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LASER COMMUNICATION

by

Su Yu

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LASER COMMUNICATION

SU Yu

Communication has had a very important function in three great revolutionary movments, the class struggle, production struggle and scientific experiments. The rapid development of industrial and agricultural production, transportation, the defense industry and the science and technology of our country have made newer and higher demands. "People must always summarize experiences, have discoveries, have inventions, have creations, and have improvement." This also pertains to communication. It started from wire and progressed to wireless; from long-wave to microwave; from transmitting signals and voice to pictures and moving images; from ground communication to satellite communication, space communication, and so forth. These are in a continuous process, and are continuously marching on toward the goals of large capacity, longer distance, miniaturization, etc.

The appearance of the laser has provided a strong tool in realizing these goals and attracted a lot of attention. Laser communication has become a part of the communication field. Though laser communication is still in the research stage, after more than a decade of effort the practical laser telephone has been made, multichannel transmission has been tried, laser television photography and large color screen viewing have been realized, and now

the tests and research of laser communication between spaceships and the ground and laser around-the-world communication relayed by artificial satellite are in progress.

We use a practical example of a semiconductor laser telephone to illustrate what laser communication is.

The transmitting system of a laser telephone is composed of a gallium arsenide semiconductor laser and transmitting optical system. The former produces an invisible infrared light with a wavelength of 0.8 to 0.9 meter. Audio signals are transformed from a modulator to an electrical pulse, which then is used to control a pulse generator which is directly connected to the electrodes of a semiconductor laser to carry out the function of modulation. Here the laser is used as a carrier, and the audio signal is used as modulating wave. The modulated laser carrier signal is transmitted through a transmitting telescope (equivalent to the transmitting antenna of radio communication) to obtain a near-parallel light beam. The receiving antenna is also a lens which focuses the signal light beam on a photoelectric element - a photo diode; the output electrical signal, after amplification, goes into a demodulator and then is converted back to the original audio signal. Two stations with communication equipment of same transmitter and receiver systems, after being pointed at each other, can talk to each other (Fig. 1).

It is obvious that laser communication equipment is generally divided into two parts, the transmitting and receiving systems. The transmitting system is generally composed of a laser, modulator, transmitting telescope, etc. The receiving system is composed of a receiving telescope, electro-optical receiving elements, amplifier, demodulator, etc. In addition to the transmission and receiving portions, some communication systems also have a signal transmission portion, such as an optical fiberglass waveguide.

Laser communication draws so much attention mainly for the following reasons.

First, laser communication has large informational capacity, and more transmission paths. We know that the channel capacity is proportional to the bandwidth of the channel. The wider the bandwidth, the greater the capacity. The frequency of a light wave is very high, about 10^{13}~10^{15} Hz. Assuming that each sonic bandwidth is 4,000 Hz, it could hold 10 billion talking lines; if each television channel takes a 10-megahertz bandwidth, it could broadcast ten million television programs simultaneously without any interference. This is a tremendous message capacity that radio wave and microwave communication system could never reach in the past. Even the simplest semiconductor laser telephone has several lines for telegraph transmitting and several lines for telephoning at the same time.

Second, laser communication has better security. We know that electromagnetic waves have a diffractional phenomenon. Due to diffraction, the transmitted wave beam of the antenna and the divergence angle are proportional to γ/D (that is the wavelength is proportional to the diameter of antenna). Therefore the shorter the wavelength, the larger the diameter of antenna and the smaller the divergence angle of the wave beam. Because the wavelength of a light wave is much smaller than that of a radio wave, the divergence angle of a laser light-wave beam is also much smaller. For a light wave with a wavelength of 1 micron, if the transmitting antenna is a lens 20 cm in diameter the divergence angle of the transmitted light beam is only 1.1 degree. But for microwaves in the use of radio waves, a huge antenna is used (such as one having a diameter of several dozen meters) and the divergence angle is several degrees. A small divergence angle means that the energy is concentrated in a narrow region, thus enabling the message to be sent over a very great distance. This is very important to satellite communication. For instance, a relay satellite could be put into a synchronous orbit to transmit a laser message sent by a

close-to-ground operating satellite to a ground-based station (title picture). Not only is the divergence angle of the laser beam small, but it also uses invisible light; thus it is not easily intercepted by the enemy and it is well secured.

In addition, the structure of the laser communication equipment is light and the facility is economical. Due to a small divergence angle of the laser, the directivity is good and both transmitting and receiving antennea for optical communication could be made very small. The diameter of such an antenna is several dozen centimeters, and the weight is only several dozen kilograms. But for a microwave antenna with a similar function, the weight is much heavier and the volume is much larger. Therefore, laser communication on the ground could be suitable for the classified communication of the portable type, short-distance, point-to-point, or other special occasions (Fig. 2).

Nevertheless, all things are looked at in two ways. The optical communication has its special advantages and, at the same time, it also has its weaknesses. These are mainly:

1. Atmospheric attenuation is serious. The light wave is rather greatly affected by the atmosphere and weather in the process of propagation. Cloud, fog, rain, snow, dust, and atmospheric turbulence, interfere with the propagation of light, thus seriously affected the distance of communication.

2. It is difficult to aim. The laser beam has very high directivity. This is an advantage, but it also brings some difficulties in aiming between the points of transmission and reception. If the accuracy of aiming to a radiant second is required, the requirements of the precision and stability of the facilities are very high, and the operation of the facility is also rather complicated.

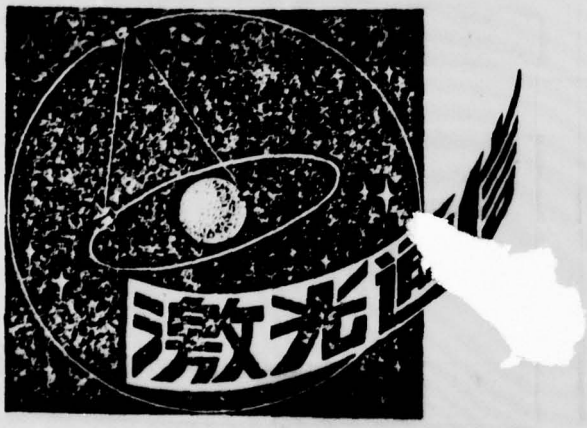
3. It cannot pass through an obstacle. The light beam cannot go around an obstacle in the process of propagation; therefore the communication region is limited.

It is obvious, the laser communication cannot replace radio communication, since there are advantages and disadvantages. We should fully utilize these communication means to compensate each other and contribute to the work of building socialism.

Because the laser is absorbed, scattered, and affected by atmospheric turbulence while being propagated in the atmosphere, it is greatly attenuated and disturbed; thus, the reliability of laser communication is greatly decreased. Generally speaking, the closer to the ground, the more serious the effect. Based on this, the use of laser as a means of space communication and satellite communication has great significance.

To conduct laser communication on the **ground**, optical fiber is considered most for an optical waveguide to conduct the transmission of the laser (Fig. 3). An optical fiber is a thin fiber of transparent material. It conducts light based on the principle of total reflection of light, as shown in Fig. 4. Light goes into the fiber in the direction OA. When the incident angle δ is greater than the critical angle (it is determined by the refraction index of the component **material** of the optical fiber), light is not refracted but only reflected, it is called total reflection. Now light travels from A to B, and has another total reflection, thus light is propagated along the lines OABC..... Optical fiber has very high penetrance with a laser. The attenuation with the best fiber has only several decibels per kilometer. Thus with such a low attenuation it is practical to use it in optical communication. Such an optical fiber resembles an underground cable, and may be called an "optical cable." The size of the optical cable is small and it can be bent. Light can be sealed in the tube and there is no scattering or radiation. Hence, it can be concealed for secret communication. The optical cable does not produce any

communication. The optical cable does not produce any electromagnetic interference nor is it disturbed by electromagnetic interference. There is no need for tremendous construction work to lay the optical cable. If the communication distance is too far, a relay station can be added appropriately for amplification. So to use optical cable for laser communication is a branch of laser communication with a most promising future.



Title picture

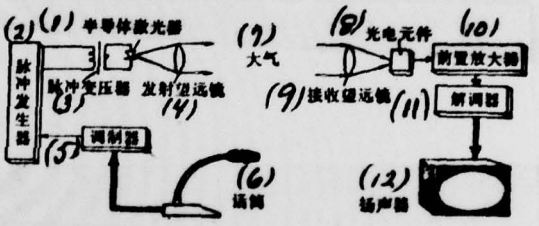


Fig. 1. Diagram of the principle of laser telephone.

KEY: (1) Semiconductor laser; (2) Pulse generator; (3) Pulse transformer; (4) Transmission telelens; (5) Modulator; (6) Microphone; (7) Atmosphere; (8) Electro-optical element; (9) Receiving telelens; (10) Prime amplifier; (11) Demodulator; (12) Speaker.

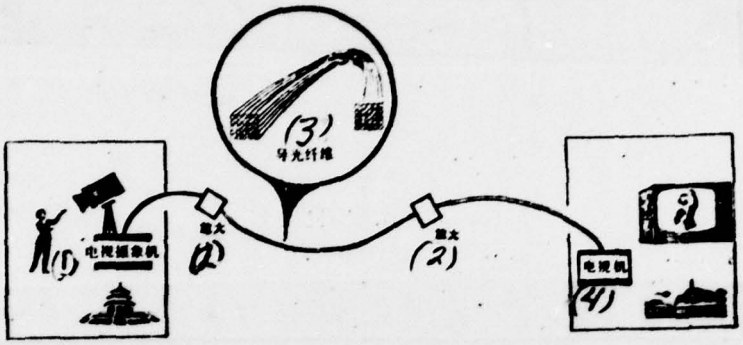


Fig. 2. Laser communication between islands.

KEY: (1) Television camera; (2) Amplification; (3) Optical fiber; (4) Television.

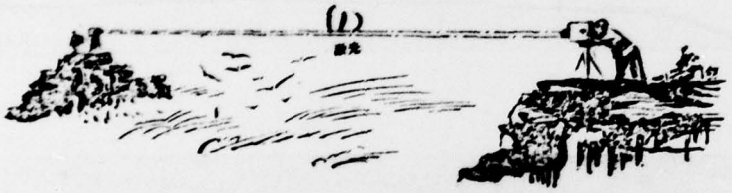


Fig. 3. Television transmission by using optical fiber.

KEY: (1) Laser

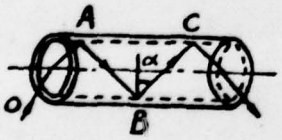


Fig. 4. Diagram of the principle of optical fiber.

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